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ABSTRACT

This monograph deals with the kinds of elementary school science programs available today and how schools might go about choosing among them. The author advocates that every elementary school should have science classes for three or more periods each week; elementary school science is best taught as a "hands-on" subject; elementary science activities should be taught by the regularly assigned teacher in a self-contained classroom; elementary science activities should be aligned to progression of elementary skills, knowledge, and concepts; and non-textbook programs should be employed, or if textbooks are utilized, frequent science activities for all children should be embedded in the science program. (Author/SL)

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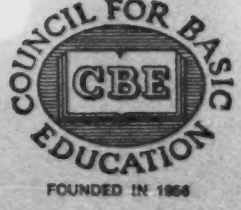
Choosing a Science Program for the Elementary School

by

HOWARD J. HAUSMAN



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Choosing a Science Program for the Elementary School

FOREWORD

The Council for Basic Education believes that all students, except the severely retarded, should receive adequate instruction in the basic intellectual disciplines. Science is one of those disciplines, and this is the first paper devoted entirely to science in our series of occasional papers.

Dr. Howard J. Hausman, a long-time member of the Council, recently retired from the National Science Foundation, where for many years he had worked on pre-college programs in science. We asked him to set forth his views about what science in the elementary school should be. Most of his monograph deals with the kinds of elementary school science programs available today and how schools might go about choosing among them. We publish his knowledgeable and forthright paper in the hope that it will stimulate productive discussion of this important curriculum area. We are grateful to him for this contribution to our work.

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WHAT SHOULD SCIENCE TEACH?

Young children are very curious about the world in which they are growing up. They seem to be attracted to living things and physical phenomena, and to be fascinated by explanations about them. They like to handle objects to see what can be done with them. In a broad sense, this is the subject matter of science. In the right environment their lively curiosity can be stimulated and discreetly channeled into an invitation to learning. Science in the elementary school not only provides the base for later, more formal courses requiring greater maturity, but it is intrinsically interesting. It helps to make school an attractive place. A Massachusetts study of elementary school science revealed that a quarter of the children chose science as their favorite subject, and half like it as much as any other single subject.[1]

Science should teach more than facts and mechanical skills. It should help develop children's abilities to think critically, to seek and use evidence before jumping to conclusions, and to begin developing some of the other more complex intellectual skills. Educators expect science to make unique contributions in these facets of human development, according to their public statements. Their professed objectives for elementary science were recorded by Blackwood, who surveyed the status of elementary science teaching in 1961 for the United States Office of Education.[2] When school officials were asked to rate the importance of a number of science teaching objectives for their schools, the two at the top of the list were:

> Help children develop their curiosity and ask What, How and Why questions.
>
> Help children learn how to think critically.

The same two objectives turned up at the top ten years later in a survey of Pennsylvania public school principals and teachers, followed by:

> Help children develop problem-solving skills.[3]

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[1] *Something of Value: A Summary of Findings and Recommendations for Improving Elementary Science in Massachusetts* by D. K. Whitla and D. C. Pinck. Cambridge, Mass.: Office of Instructional Research and Evaluation, Faculty of Arts and Sciences, Harvard University, 1973.

[2] *Science Teaching in the Elementary Schools (A Survey of Practices)* by P. E. Blackwood. OE-29059, Circular Number 749. Washington, D.C.: U.S. Department of Health, Education and Welfare, 1965.

[3] *Science Teaching in Pennsylvania Public Elementary Schools: A Report* by J. T. Belluci, I. T. Edgar, C. A. Guerriero, and B. N. Belluci. Wilkes-Barre, Pa.: Educational Development Center, Wilkes College, 1973.

Similarly stated language appears prominently in the educational objectives written by state and local systems over the whole country. The State of Virginia offers this rationale for teaching science in its 1972 *Elementary Science Guide*:

> The elementary science program should enable children to:
>
> Develop attitudes and values which in daily practice assure a quality environment;
> Develop skills needed to seek and evaluate information;
> Use experimentation, discovery, and research with a variety of materials to find answers to questions;
> Develop concepts which are formulated upon basic scientific knowledge;
> Relate the contribution of science to the improvement of life.[1]

The Virginia guide continues by spelling out somewhat more specifically what is meant, in terms of *awareness* (e.g., difference between fact and opinion, reliable sources of information and data); *attitudes* (e.g., open-mindedness, initiative, self-direction); *skills* (e.g., critical thinking, using basic processes of science); and *understandings* (e.g., of important concepts, applications of scientific knowledge in daily living).

These are indeed praiseworthy goals. Bringing them into the classroom, however, is a large order. In no way is it critical of Virginia—and other jurisdictions with comparable statements—to point out that there is a long chain of communication between this document, with its many valuable concrete illustrations, and the local school system, down to the school building and the elementary classroom teacher. Given the many important responsibilities of the elementary teacher, one can hardly expect him to puzzle out without considerable assistance how to integrate the teaching of concepts with adequate experimentation and devising reliable sources of data. The elementary teacher is very likely to have had minimal or no education in science. His natural reaction is to seize on the factual material in the science syllabus, plus the written statements of scientific principles, as the only understandable elements of the science curriculum he can handle.

A very conscious effort must be made to prevent the state and local curriculum guides from becoming merely public relations documents that profess concern for inculcating the attitudes, awareness and understandings to which society subscribes. The contribution of science to intellectual development must be carefully illustrated for

[1] *Elementary Science Guide, K-7.* Richmond, Va.: Division of Elementary Education, State Department of Education, 1972, page 5.

the average teacher. To quote once more from the Virginia guide, the simple process of measurement is discussed:

> Measuring involves developing a comparison or quantitative description of such properties as length, area, volume, weight, temperature, or pressure. Both standard and non-standard units are used in the development of the skill.[5]

This passage may seem self-evident to some. Yet specific attention must be directed to the process because of the inadequate preparation of the average teacher. Historically, science teaching in the elementary school has seldom been concerned with measuring, particularly at the beginning levels. It has been descriptive and verbal, rarely asking *how much larger, how much farther, how many more.* Experience has shown that teachers need instruction on how to bring notions of quantitative comparisons, or measurement, into their teaching. The Virginia guide does provide examples in several contexts; the teacher will need practice and encouragement to use these and to develop his own.

What science should teach, the major question addressed by this paper, is determined by its singular potential for fusing interesting material with development of intellectual power. Obviously, content is highly important. Selection of appropriate topics, formulation of concepts in understandable terms, use of carefully chosen experimental materials that will reveal the significance of the content—these are necessary but not sufficient conditions. The challenge and the opportunity in teaching science exceed the bounds of content. Habits of thinking and positive attitudes should have equal priority. Rather than treating these objectives as only by-products of the more concrete content material and student activities contained in the course of study, the schools should focus attention fully on opportunities for practicing the processes of science: observing, classifying, measuring, inferring, predicting, interpreting data, experimenting, hypothesizing, etc.

Without the *thinking* elements science teaching is stripped of its greatest appeal to children. Frequently it is not advisable to attempt teaching these processes directly. The teaching environment then has to be organized so that these effects surface naturally. Only by engaging children actively in science investigations can the schools intentionally achieve the less tangible learning objectives. Through

[5] *Ibid.*, page 8.

carefully designed student investigations the praiseworthy objectives in state and local curriculum guides can be realized, instead of serving as unattainable window dressing.

This approach to science teaching is entirely feasible. It is happening today in thousands of classrooms. However, it took a lot of work to accomplish.

TEXTBOOKS: THE PAPER CRUTCH

Scene from a Classroom

Twenty-six third-graders are seated at tables in more-or-less straight rows, an open textbook in front of each. The teacher points to the window and asks: *How do you know whether it is windy outside?* "If the wind is blowing." *But how can you tell if you're in here?* "Trees are bending in the wind." "You can see the clouds." *Clouds doing what?* "Moving in the sky." *Can you see the wind itself?* "No." *How do you know it's there?* "It moves things." *Does the wind do work? Maria, read the first paragraph.*

Maria reads aloud, "Air can do work." The passage relates what happens when a gust of wind arises. Pictures on the page show hats and other objects blown around, and some other obvious effects of wind. *Eric, you read the rest of the page.* Still air is contrasted with moving air. Still air does no work, but moving air can do work. There are examples.

James, read the next page. There is a picture of a toy sail boat on a pond with sail inflated, and a kite in the air. The book restates that still air does no work and moving air does. Moving air has force. Referring to the picture, the text asks for evidence of the force of moving air. The teacher repeats the question. "The sailboat is moving." "So is the kite." The page closes with references to the words *work* and *energy.*

Carla, read the next page. This contains a picture of a farm with animals and a windmill prominently situated at one side. Carla reads aloud that the farm has many animals and they need water. However, there is little water on the land and it has to come from wells. She reads the question, "What does the windmill do?" The teacher repeats, *Can anybody guess what the windmill does? Yes, Joey.* Joey says, "The windmill turns from the force of the air and works a pumping machine. This lifts water from the well into a water tank for the animals."

Carla then reads directly from the text: "The windmill turns from the force of the air and works a pumping machine. This lifts water from the well into a water tank for the animals." She reads on about windmills operating machines to supply electric power. Then come other examples of "energy from moving air."

Roger reads from the next page about the source of the wind's energy: the sun heating the earth. The air gets hot and rises. Cooler air moves in. The moving cooler air is a wind.

Several children are moving restlessly, playing with pencils and whispering. The teacher calls for attention, as he has done twice before during the reading. *What work was being done?* No answer. *Did the wind do any work?* "It blew a windmill." The restless movements persist. There is another call for order, a period of enforced quiet. The books are collected and shelved.

After class is dismissed, the teacher remarks that the text (published in 1966) is difficult for many of the children. They are poor readers and have short attention spans. He would like to ask questions suggested by the teacher's edition, but the children seem often to get confused because the questions are too theoretical. It works best when he can ask a question that the book answers within a short space.

Speaking of the student activity kits which are a recommended but optional component of the publisher's program, he states that they take time and a lot of assistance from him. There isn't much time for science, so he hasn't used the kits at all this year. Anyway, the book explains a lot. He and two other teachers share a set of kits supplied by the text publisher. They are in the storage room. (Later, the observer saw these kits. All but one compartment appeared to have been undisturbed, with materials in their original wrappings, sealed with tape. At some time in the past, one drawer's contents had been used. The kits had been in the building for an undetermined period, predating the arrival of the assistant principal four years before.)

Like the great majority of elementary science textbooks, the one used in this class is totally expository. Questions are interspersed among the statements, but they are mainly rhetorical. Almost any query appearing in the text is answered either immediately below or on the next page. The question then becomes a transparent device for expounding further information, requiring no thought and undermining the meaning of an inquiry. Note the sequence described above with the question "What does the windmill do?" It is answered in the very next sentence. One student glibly read the answer aloud in response to the teacher.

Examining the windmill passage further, the entire treatment was meaningless to these children. They live in a middle class suburb of a very large metropolitan area. Their experience with windmills has been in picture books. They had no idea what a pumping machine is, much less how a windmill can operate one. For them, a well is something you see in pictures that has a bucket attached to a rope on a handle. How it relates to a pumping machine is unexplained. As for how a windmill can generate electricity for a farmer, and what the farmer does to use the electricity, these things were far beyond their ken. Their understanding of the terms *work* and *energy* was never established in the class, although skepticism on this point is probably justified. However, the teacher felt that he had to read this section in sequence in order to reach the later sections which sum up the concept-mastery goals for the semester.

This was a science reading lesson, with the added handicap of many children reading below grade level. There is an illusion in the text of suggested student activities, using the science experiment kit in the storeroom. Their value is questionable, because the results the student should obtain are quickly revealed and explained. This leaves no incentive for the teacher to use them as a means of instruction—"Anyway, the book explains a lot." Little knowledge and much boredom were the results of this class.

The student who can keep abreast of the text measures success by rote memory. The end products are word and concept definitions: *What is a force? What do we mean by work? When does a force do work?* Work is ..... Energy is ..... Give examples of work done by the wind. The principal sources of energy are ..... A child can successfully talk and write glibly about forces and work without physically having experienced what he is talking about. Experience is not obtained in the classroom, but sometimes outside experiences are invoked. During a lesson on air pressure the students may be reminded about blowing up a bicycle tire. Perhaps all of them have blown up a bicycle tire, perhaps not. At the text's bidding those who have done so may be able to recall the force of air pressure as the tire inflates. This recall may be the most concrete "experience" with air pressure the children have in the classroom.

This is a typical case of *the paper crutch*. How does the textbook dominate so completely? Part of the answer lies in the attitudes of many people, including elementary school teachers, toward science. Knowing very little about the sciences, having avoided science courses in high school and college, elementary teachers must have something authoritative to lean on. The textbook has the answers to all the topics that are safe to cover. The encyclopedia is the ultimate in answers. All that can be taught must be written down. Any departure from this safe path may allow everything to unravel, leaving the poor teacher naked before the children, revealed in all his ignorance.

To control the class and preserve the teacher image, stick to the book. It gives the facts, states definitions precisely, and supplies the required concepts. Avoid unpleasant surprises with demonstrations which may not work. Especially be wary of children handling apparatus in class on their own, because one cannot be sure of the results and, anyway, it becomes too disorderly. Just ration out the words and definitions in the text and the students will spit them back. As a bonus, their vocabularies are increased.

The textbook industry did not create this condition, but it has perpetuated the syndrome. Elementary science text series are written under the editorship of professionals. An article of faith among science educators is that children's active involvement—"hands-on" activity—is the *sine qua non* of science learning. Invariably the teacher's edition of the text exhorts the instructor to carry out faithfully the suggested student investigations. Just as invariably the books are written in such a way that the teacher can gracefully by-pass them. The *Concepts in Science* series, published by Harcourt Brace Jovanovich, has captured a large share of the elementary science textbook market. The introduction to the 1972 revised edition states: ". . . the use of the Classroom Laboratory Sets is optional." The text's continuity is not spoiled by omission of the suggested student investigations.

Given such subtle disincentives, the teacher who feels insecure about setting up the routine exercises suggested by most texts welcomes the excuse to omit them. Even though the expected results are given in the book within a page or two, it takes time and too much can go wrong. Anyway, the book explains it. Science is a reading lesson—when there is time for it.

It is no exaggeration to say that the textbook dictates the school's curriculum. When a school system adopts a text series, the publisher's scope-and-sequence chart is essentially adopted by the system. The *Concepts in Science* chart may be seen on teacher room walls all over one large system that adopted the series in 1970. It is much easier to read and display than the bulky official curriculum guide for the system, which practically repeats it. Another system of about the same size had adopted an earlier edition of *Concepts in Science*, but changed to one of the no-text, student inquiry programs in 1971. Because the state curriculum guide showed a structure derived from that text series, and since state aid depended on following these guidelines, the local system had to superimpose its new no-text program components onto the chart of the commercial publisher and show how each segment was covered in its new adoption.

School syllabi and commercially published texts have a tandem relationship. Periodically a school system's science curriculum is overhauled. Five years is a common interval, for texts often are given a life span of that duration. The practice is to appoint a local committee. Starting points are the current course of study and the latest state guidelines. The committee calls for recent text series. The mem-

bers study the thematic structure, treatment and grade placement of topics, and all the other elements required by their list of criteria. Publisher's scope-and-sequence charts provide convenient summaries of their texts. The committee then constructs a consensus position of the texts, making possible a number of alternatives. This becomes the new syllabus.

A similar process is followed by the states. The twenty-two states with mandatory textbook adoption policies are more closely tied to currently published programs than the remaining states, but all periodically update their guidelines.

The textbook series published in the 1960's appear quite similar to each other in important respects. They include the same topics and they agree on their grade placement. One text seems much like another in vocabulary, demonstrations, coverage of concepts, and use of rhetorical questions. They do have qualitative differences that make one appeal more to a selecting committee than another, such as writing style, illustrations, suggested student exercises, reading levels, organization and discussion of topics, teacher editions and publisher services.

Publishers periodically turn out new editions. Since state and local systems choose texts on a fixed schedule, each publisher needs a recent copyright date, whether the revision is fundamental or cosmetic. No publisher wants to be dropped by a state, and every publisher not now on an approved list seeks to be added. Publishers examine state and local curriculum guidelines for conceptual themes and topic placement. Their new editions tend to reflect a consensus position across school systems.

Since the schools look at what the publishers are doing and the publishers look at what the schools are approving, convergence is certain. Unfortunately, this leads to the lowest common denominator, or what is acceptable to the widest range of potential adopters. A distinct departure from the consensus position exposes the publisher to high risk. Conversely, if a school system wants to break out of the circle and reject all published materials, it is forced to develop its own. Not only is that expensive but it calls for a high level of expertise in several fields, which a school system is not likely to possess.

In simplified fashion, this description covers the situation up to the beginning of this decade. In many locations it is still going on.

Increasing dissatisfaction with textbooks' reliance on language alone, and complaints about reading difficulty and unsuitability of the conceptualizations in the texts for children in the intermediate grades, failed to break the pattern until the appearance of the "inquiry" science curricula. Blackwood's 1961 survey showed that 82% of the schools had adopted a textbook for the primary grades and 95% for the intermediate grades. His comment: "Science textbooks play a key role in determining what content is studied in the elementary school."[6]

Given the similarity among textbooks, a handful of commercial publishing companies have been controlling what our children learn in science for many years. A curious breakthrough has occurred within the last four years or so, however. Since state and local science specialists try to keep their guidelines up to date, the recent spread of "inquiry" materials has resulted in their appearance among the curriculum guides, at least as options. This has been reflected in the behavior of publishing companies, as will be seen in the later section entitled "The New Breed: Text and Activity Entwined."

[6] *Science Teaching in the Elementary Schools (A Survey of Practices)* by P. E. Blackwood. OE-29059, Circular Number 749. Washington, D.C.: U.S. Department of Health, Education and Welfare, 1965.

"HANDS-ON" SCIENCE

Scenes from the Classroom

I

There are 24 children in the first-grade class, distributed around the room at their tables in pairs. Each child has a plastic tray of objects that were selected from displays containing: stones of varied sizes, color and appearance; small pieces of metal; pieces of wood quite different in color and weight; a large collection of buttons; shells of many types; geometric shapes made of different kinds of plastic; various rubber products; bits of carpeting; paper and paper-based materials; putty, ceramics and miscellaneous materials. The teacher asks, *Who would like to describe an object on his tray?* A child holds up a stone and says, "This is black and white and shiny, too. On one side it's smooth. It's rough on the rest of it. And—it's kind of square." *Are there any other properties your object has?* No answer. *What properties did James name to describe his object?* "He told us the color and if it was rough or smooth." "He told us its shape." *What else could he have told us about his object?* "Is it hard?" "Can you see through it?" This child holds up a piece of clear plastic, peering through it at the window. Size and heaviness are also mentioned. *Mark, you may describe an object on your tray, but don't show us which one. Susan and Larry will try to guess your object.* Mark describes a piece of hard rubber. Susan points to it. Larry agrees. The teacher suggests they pick it up and verify all the properties. The children then return to their partners, and each describes an object on his tray which the other is supposed to guess. When a child cannot select the object described, the two partners discuss what properties would have helped to describe it more fully. *Now, each partner arrange your objects according to some properties. Don't tell your partner what your properties are. Let him guess.* As the teacher walks around, some children tell her they can't put all their objects into the properties they selected. She advises them that they may leave some out if they wish. Correct guessing by partners occurs more than half the time. Each child then tells the class what properties he selected. They report "big and little," "heavy and light," "soft and hard," "color and white and no color," "sort of round, sort of square, and long." (*What property is that?* "Shape.") One girl chose "things I have in my house." Another chose "things that grow."

II

A second-grade class lines up and proceeds to the school yard. It is a bright, sunny day. Each child has a square of paper, somewhat shiny on one side. A small object, a cardboard cutout of an animal shape, has been taped to the center of the paper. The children hold their

papers up and observe. Soon excited comments are heard. "My paper is getting dark." "So is mine." "Hey! Look! It's not dark under my little cat!" "I can see my little bird on the paper." "It's dark all over except where my bear was."

Back in the classroom, they discuss the change in the paper. One child has taped her cardboard dog to another piece of paper, but no change has occurred. *What do we call it when a change has been caused?* "An interaction." *What could be interacting?* No answer. *Did the interaction have something to do with being outside?* "It was windy outside." "It wasn't cold." "It was sunny." "Was it the sun—like sunburn?" *Could you experiment in here to find out if that might have been part of the interaction?* They discuss sunny weather, and brightness or light is mentioned. Several children start to talk about using a light. The child with the cardboard cat wants to know why the cat part was not dark, and then voices the thought that maybe the cat got in the way of the sunlight, like a shadow. Some table lamps are set up around the room, and the experiment is repeated by having the photographic paper squares with the cutouts taped to them exposed to the lamps. Soon they verify the effect of light. *What evidence do you have that light caused the change?* Then, finally, *What was interacting with the light?* "Something on the paper."

III

In a fourth-grade class each child is given a size D dry cell (battery), one flashlight bulb, insulated wire with the ends scraped bare, and some other pieces of apparatus. The challenge is to make the bulb light up. In the end all children are successful, although after a period of frustration some learn from their neighbors. The early learners—not necessarily the best readers in the class—discover the use of "bulb holders." They start to connect batteries, light up several bulbs simultaneously and otherwise experiment. The teacher encourages them to predict what will happen before they connect the bulb(s). In discussing their results they can describe how they lit bulbs, and they show recognition of an interacting system at work. The idea of an energy source remains latent. The class ends with the teacher promising that they can continue tomorrow.

IV

The children in a fifth-grade class are absorbed with measuring temperature changes in water. They are carrying over work started two days before. One team of two children wonders what the temperature of two tumblers of water would be if they were mixed, one having been warmed at the radiator and the other drawn fresh from the cold water tap. They have a container larger than either tumbler, but notice that it cannot hold the contents of both at the same time. They surmise that the temperature should be midway between the

two. They measure the temperature of the water in each tumbler and average the two. By this time they have involved the teacher, who calls the class to this corner. Other children devise a way to test the result by reducing the quantities in the two tumblers by equal amounts, then pouring them into the larger container. They measure the temperature of the mixture and verify the prediction of the average temperature. They detect a slight discrepancy, however. The teacher promises to have this discussed later.

They continue their study of heat energy by measuring the amount of water melted from ice cubes in a standard time period. Each team devises its own measuring techniques. Some are pretty sloppy with spillage, and others make very hasty judgments on quantities of melted water. They learn from each other, however. Eventually, all use the cylinder with the convenient spout and the graduated metric markings. By now they all want to "get it exact" in cubic centimeters. The measured amount of melted ice for each team is marked graphically on a histogram drawn on the chalk board. Not all amounts are in agreement, so that a scatter is apparent in the graph plot. They start to discuss the meaning of this.

The Alternatives to Textbooks

During the early 1960's a movement began to offer elementary schools genuine alternatives to textbook science. Educators seemed to agree that children's first-hand experience with objects and laboratory investigations was essential to achieve deep instead of superficial learning of science. Even textbook authors paid at least lip service to this principle. Several groups proposed to develop entire science curricula organized around investigative inquiry, using material objects. They wanted to show that the important ideas considered basic to scientific understanding could be translated into experiments suitable for elementary school children of different ages. They planned to demonstrate that coherent programs of increasing depth could be devised from laboratory involvement at least as well as from a coordinated textbook series, thus providing factual information and enunciation of concepts but also adding dimensions that textbooks seem unable to contribute.

Student activities in science—such as observing plant growth, caring for animals, nature walks and simple science experiments—have long been familiar practices in science teaching. Blackwood's 1961 survey showed that a minority of teachers consistently used these techniques, while others did occasionally. These practices, however, almost always were adjunct to, rather than central to, the science program.

The work of the Swiss child psychologist Piaget has influenced elementary science education in the United States. Piaget had carefully observed children's intellectual development. He concluded that younger children are qualitatively different from older children in dealing with problems, as though different aspects attract their attention and govern their reactions. His explanation was that there are well-defined stages of growth through which a child must pass before being able to structure his perceptions in keeping with more mature understandings. For example, if two round balls of clay with the same amounts of material are presented, changing the shape of one from round to elongated will lead young children to see one as having more clay than the other. At a slightly more mature stage the child may realize that a change of shape does not change the amount of clay, but he may still be confused if one of the balls is broken up into a number of small pieces. Then he is likely to believe that there is more because there are a lot of pieces. Abstractions cannot be expected of the child until he has reached the appropriate developmental stage. Reliance on verbal explanations at too early a stage is not only futile but can cause negative attitudes toward learning. A discussion of the application of Piaget's work to science education may be found in a book by Thier.[7]

Translating these ideas into a science curriculum means providing children with a literal feel for what they are supposed to be learning. Doing—engaging their senses of touch, balance, sight, and sound—is essential. Kinesthetic experience carries more information than torrents of language, even more than a few well-chosen words. Science teaching must keep children in touch with the real, physical world as we seek to have them describe and explain it.

In recent years, support was obtained from the National Science Foundation for trial of several approaches to the investigative, or inquiry-oriented, strategies of science teaching. After an initial trial period some projects were terminated, but most of the major projects were carried through to completion.

In general, the projects emphasize the child's engagement in a task that is intrinsically interesting. A challenge is posed, and the child has a chance to respond with appropriate materials at hand. The situation is open enough for the child to try without embarrassment, to make a mistake without penalty other than to try again, to exhibit

[7] *Teaching Elementary School Science: A Laboratory Approach* by H. D. Thier, Lexington, Mass.: D.C. Heath and Company, 1970.

lack of skill and still receive support. There may be no single "right" answer to an investigation, the results depending on conditions chosen by the child or his team—which materials used, what temperature, at what angle the equipment is set, etc. Questions are often voiced by the teacher, but a large proportion are divergent: How are these the same and how are they different? Why does this happen? What would happen if . . . ? Find a way to determine if this explanation is correct. What results do you get? Tell us what you observe. Describe, find out, experiment with, manipulate, compare, keep a record. Did you get the same result? Why was it different? Measure, weigh, classify, explain, verify.

As the children perform these investigations, they appear to be enjoying themselves. It is not aimless play. Structure has been built into the tasks in a sequence of activities. In the end the students will have mastered major concepts, knowing them as only actual experience can demonstrate them. Along the way they will also have had to exercise imagination, to seek evidence, to rely on observable data, and to explain the evidence of their senses. The important intangibles of science objectives—understandings, attitudes, and awarenesses—are as much a part of the curriculum as the obvious content.

The projects discarded the traditional student text. In a sense, however, each developed a new kind of text—teacher guides that describe the philosophy of the project and explain in detail every investigation together with its purpose in the larger scheme. Related readings offer content information to the teacher for greater depth in specific topics and frequently supply supplementary student activities and readings. Beyond the written and pictorial materials for teachers, educational packages are provided to assist those who organize in-service training for teachers.

More than any other factor, the materials directed to teachers focus on appropriate strategies for teaching elementary science through inquiry. A child must have a chance fairly often to discover some simple relationships for himself. He must not be told everything. Inquiry must be genuine. Investigations must not be merely disguised, carefully structured walking through the paces. The child must exercise thought processes other than imitation. Therefore, one of the beginning lessons for the teacher is to avoid helping the child too much. Responsibility for learning must visibly rest on the child. This point is well stated in a passage from a teaching manual used in the Philadelphia schools:

It is much easier to tell a child what we wish him to know, rather

than to wait for him to discover it for himself. The inexperienced teacher can rarely resist the temptation of telling the child all the facts. . . . The teacher's behavior is relied on to convey the scientific ethic that science requires an open mind and willingness to question and change beliefs on the basis of observable reality requiring personal doing, not watching.[8]

Each curriculum project has a unique approach that appeals to different ideas on how science should be taught. Choices are left to local schools as to which suits their style. They are described here in the order in which they appeared on the market.

Elementary Science Study (ESS)

Fifty-six self-contained science units have been produced. They can be inserted into an existing science program or be strung together at the school's or the teacher's discretion to constitute the entire science program. Some units can be completed in a couple of weeks (assuming a daily or three-times-a-week science class), while others may occupy the class for a large part of the semester. Each unit is adaptable to a broad range of age levels, although the developers have indicated a modal grade as an index of maturity required.

Interesting and familiar objects form the largest part of the materials recommended in these units. However, some simple pieces of equipment had to be especially designed, such as a very cheap, small microscope made of wooden parts and bead lenses; or a small wooden balance with plastic or paper cups as containers. While one might expect most of the materials to be locally obtainable, experience has shown that collecting them is usually an insuperable job for the individual teacher. Therefore the ESS units are shipped as complete kits. The kits contain teacher guides, student work sheets, and all necessary objects. Some units have supplementary booklets for students seeking more information. Background readings for the teacher are available. Films and film loops may also be purchased.

The unit titles offer a suggestion of the flavor of this project. Here are a few:

> Mystery Powders; Small Things; Mirror Cards; Microgardening; Match and Measure; Pattern Blocks; Batteries and Bulbs; Kitchen Physics; Behavior of Mealworms; Brine Shrimp; Attribute Games and Problems; Clay Boats; Colored Solutions; Where is the Moon?

[8] *Implementing Elementary School Science in Philadelphia.* Philadelphia, Pa.: Division of Science Education, The School District of Philadelphia, no date [1973?].

Non-directive teaching is required. Children's exploration of the materials is encouraged. At first glance ESS may appear to lack structure. This is deceptive. The structure is in the materials and the investigation process. As he works progressively through the unit the child gains a sense of the inherent structure along with facts, principles, and new skills.

ESS was developed at the Education Development Center in Newton, Massachusetts. Its originators came from the same team that had started the curriculum reform movement in science with the high school physics course, PSSC. They were headed in the beginning by the MIT physicists Jerrold R. Zacharias and Francis Friedman. It is distributed by the Webster Division of McGraw-Hill.

ESS is the most flexible of the new, inquiry-oriented science curricula. Schools differ widely in using it. In Fairfax County, Virginia, ESS is put together in sequences somewhat open to school choice, and is the elementary science curriculum. Readings for students on topics interesting to them supplement the program. In Philadelphia, ESS units are used in grades 4-6, following the more structured programs SCIS or SAPA (see below) in the primary grades. In many systems, however, individual ESS units, such as Mirror Cards, are used as laboratory exercises in text-based programs, or otherwise inserted as a change of pace.[9]

Science—A Process Approach (SAPA)

SAPA is a carefully sequenced science curriculum for grades K-6. Its guiding principle is that there are several fundamental processes underlying all the sciences, and that students in an inquiry-oriented course can and should learn these processes. Materials are selected from the life, physical, and environmental sciences. Application of the basic processes to these fields is demonstrated.

Processes appear as the central themes. For the primary grades these are Observation, Classification, Communication, Number Relations, Measurement, Space/Time Relations, Prediction, and Inference. The intermediate grades graduate into more complex themes. A Hierarchy Chart of the processes is prominently displayed and given to every teacher. It spells out the sequence which should be followed in teaching the processes, and also shows the interrelationships among them.

[9] *A Working Guide to the Elementary Science Study*. Newton, Mass.: Education Development Center, Inc., 1971.

As a concrete aid in teaching, and also as a basis for evaluating student performance, SAPA describes behaviors at every stage that indicate mastery of a process skill. Called "behavioral objectives," they provide a visible record of what each student is to learn and those which he has learned. The stated objectives and the sequences are not just an abstract educational theory. They were formulated, revised, and sequenced over and over again until their usability was established in many hundreds of classrooms.

Despite the emphasis on processes and behavioral objectives, content occupies an important place in SAPA. While they are learning skills the students are working with objects and events of the natural world. They learn and are examined for the content ideas in the scientific fields they study.

Science Materials Kits contain all the objects needed for a class of 30 students for one year's study. A teacher's guide comes with the kit. Expendable materials can be replaced with another kit. Clear labeling and instructions guide the teacher through the compartments in the materials kit. A considerable amount of printed material has been developed to assist teachers and for schools designing in-service training for teachers.

SAPA was developed by teams organized by the American Association for the Advancement of Science. Robert M. Gagne was a major contributor to its structure, with many others contributing. The distributor is the Xerox Corporation through its Ginn and Company subsidiary.[10]

SAPA's use of behavioral objectives is probably the first operational example of the technique to be introduced on a major scale. It became an example widely followed for practical application to other subject areas beyond science and even beyond the elementary level. The statement of intended student outcomes in observable terms is a decided asset, both in laying out a course and in evaluating progress. Students, parents, teachers, and administrators have all benefited from the approach in different ways. The school accounta-

[10] *Science—A Process Approach: Purposes, Accomplishments, Expectations* by Robert M. Gagne. Washington, D.C.: Commission on Science Education, American Association for the Advancement of Science, 1967. *Science—A Process Approach II: Architecture of a Revision.* Lexington, Mass.: Ginn and Company, 1974.

bility movement has adopted the behavioral objectives philosophy, which to many observers is a mixed blessing.

The use of behavioral objectives has been criticized because so many trivial and easily visible objectives find their way into accountability measures developed under directives from state legislatures or politically appointed school administrators. The more subtle and often more important objectives of education are not easily reduced to checklists of behaviors susceptible to observation or written testing in a one-time assessment. Such checklists become the *de facto* curriculum when accountability measures are rigidly applied, and the more important purposes of education are suppressed even more.

While SAPA may have contributed to this plague by popularizing the idea of behavioral objectives, it can hardly be blamed for the misuses of the concept. The authors of SAPA have been able to enunciate objective statements about important skills and processes fundamental to the genuine learning of science, although their compilation may not be in total agreement with that of other experts. They have provided instruments for assessing student attainment. It is significant that the SAPA processes or derivatives of them have been introduced into all new science programs appearing since SAPA's advent. Moreover, as older textbook series issue new editions they invariably stress the process skills which they claim are built into their programs. The contribution of SAPA is impressive if imitation is a measure.

Science Curriculum Improvement Study (SCIS)

SCIS is a structured program for grades K-6 organized around fundamental concepts in science, with both content and process dimensions. Processes are explicitly mentioned, but concepts are the backbone. There are two strands running through each grade: physical sciences and life sciences. Learning units have been prepared in a recommended sequence for each grade level in both science strands. The strategies by which the materials are presented also follow a recommended sequence: the children explore, observe, and try to interpret what they see and feel; the teacher then guides them to invent a concept which will permit a deeper understanding of their experience; eventually the children discover new uses of the concept.

Some idea of the themes may be gained from the unit titles:

Grade Level	*Physical Science Sequence*	*Life Science Sequence*
K	Beginnings	
1	Material Objects	Organisms
2	Interaction and Systems	Life Cycles
3	Subsystems and Variables	Populations
4	Relative Position and Motion	Environments
5	Energy Sources	Communities
6	Models: Electric and Magnetic Interactions	Ecosystems

As in SAPA, kits can be purchased from the distributor with all the objects needed for a year's work. The physical science and life science units each occupy a semester. Teacher guides and manuals for 32 students accompany each kit. Replacements are available for expendables.

Ancillary materials include individual readings for teachers and recommendations for in-service courses. Films, such as the delightful, award-winning "Don't Tell Me; I'll Find Out," are an important part of the training materials.

SCIS was developed at the University of California, Berkeley, under the direction of a physicist, Robert Karplus. The distributor is Rand McNally. Coming on the market somewhat later than ESS and SAPA, it did not receive as much attention as the other two projects at first. In the last four years it has spread widely. Probably as many classrooms are now using SCIS as either of the other two.[11]

Minnesota School Mathematics and Science Teaching Project (MINNEMAST)

This is a coordinated curriculum in mathematics and science for grades K-3. Its premise is that the elementary school curriculum should emphasize interrelationships between mathematics and the sciences. The project produced 29 sequential units which develop the ability to organize phenomena from a variety of sources. Content skills and attitudes are integral to the materials. Some schools are using MINNEMAST as the combined math-science curriculum in the early grades.

[11] *SCIS Sample Guide: A Composite Teacher's Guide to the Science Curriculum Improvement Study*. Chicago: Rand McNally & Company, 1970.

Kits of materials are available, together with student materials and teacher guides, from: Dr. Alan Humphreys, University of Minnesota, Minnesota School Mathematics and Science Center, 720 Washington Avenue, S.E., Minneapolis, Minnesota 55414.

Conceptually Oriented Program in Elementary Science (COPES)

Designed as a K-6 curriculum, COPES consists principally of teacher guides, one for each grade level. It confines its equipment needs to those which should be purchasable from local sources at very low cost. There are five major themes for organizing facts and theories in science: (1) the structural units of the universe; (2) interaction and change; (3) the conservation of energy; (4) the degradation of energy; and (5) the statistical view of nature. Through extensive tryout, these concepts have been brought to the level of understanding of elementary school children. Student work sheets and assessment materials ready for photocopy accompany the guides.

Most of the support for COPES came from the United States Office of Education. The later stages were completed with the help of National Science Foundation grants. Inspiration for concepts and design came from Morris Shamos of the Department of Physics at New York University. All materials may be purchased and further information obtained from: Dr. Janice Cutler, Center for Educational Research, 51 Press Building, New York University, 32 Washington Place, New York, N. Y. 10003.

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These are the major projects that have been completed after adequate trial and revision. Their quality and teachability have been extensively verified over the entire country in as diverse educational settings as could be found. The National Science Foundation publication *Course and Curriculum Improvement Projects*[12] provides additional information about all of the projects listed above.

One other project is undergoing development with National Science Foundation support at the present time and is not yet ready for general release: Unified Science and Mathematics for Elementary Schools (USMES). It consists of a number of interdisciplinary units organized around realistic problems which elementary school children can profitably investigate. Some of the units are: Pedestrian Cross-

[12] *Course and Curriculum Improvement Projects.* Publication E 74-30. Washington, D.C.: National Science Foundation, 1974.

ings: Designing for Human Proportions; Burglar Alarms; Soft Drink Design: Play Area Design and Use. Skills of mathematics and processes taught in social studies are brought into play as well as science. The work is being performed at the Education Development Center under the leadership of Earle L. Lomon, an MIT physicist. Information may be obtained from: Betty M. Beck, Education Development Center, 55 Chapel Street, Newton, Massachusetts 02160.

In addition to the articles and books stemming directly from the projects, many journal articles and books describe these programs in greater detail. For example, a book that describes application of units from ESS, SAPA and SCIS in very practical terms for teachers has been written by David P. Butts.[13]

The foregoing projects are by no means the only resources for worthwhile science activities. Individual science educators have been publishing source books for single experiments, demonstrations, and other ideas. They can be used to supplement any kind of science program.

[13] *Teaching Science in the Flementary School* by David P. Butts. New York: The Free Press, a division of The Macmillan Company, 1973.

THE TRADE-OFFS

Two cost factors connected with science programs that include student activity have caused concern—the cost of materials and the need to provide in-service training for teachers. There is little doubt that activity-based science, alone or in combination with a text, is more expensive than a totally text-based science reading program that uses the same books for several years.

Whether to include science instruction in the school curriculum is an educational decision. If it is included, whether it should be taught so that it contributes the unique values that are possible from science teaching—critical thinking, use of evidence instead of unsupported opinion, etc.—which appear in our publicly approved curriculum guidelines, requires another educational decision. All subjects in the curriculum do not cost the same. Science is not the cheapest subject at any level of education; neither is physical education. A good education requires both as parts of the total curriculum.

Cost of Materials

The base line for a discussion of science program costs is the expense of equipping a school with a textbook-based system at current prices. There are price differences among publishers, of course. Even though texts are the core and probably the exclusive medium in such a program, purchase of additional materials is obligatory. The teacher's edition, student workbooks, kits for teacher demonstrations and other recommended items are included in most publishers' program packages. Those costs are quite variable.

Latest publisher price lists indicate that a student text averages about $5.00 per student across grades 1-6. Lower grades cost less, upper grades more. For a class of 30 students the cost of texts for a school averages $150 per class. Teacher editions average somewhat over $8.00. Student workbooks, demonstration equipment and a few other items will push the average expenditure per class to the $200 neighborhood, or even higher. These items, except for workshops and occasional breakage, will last for several years.

There is another related category of expense which is part of the investment in science teaching: reference books, supplementary texts, library books, films, models, pictures, and magazines. These will cost the same no matter what type of science program is chosen.

Turning to the programs organized around student investigations, materials must be provided in sufficient numbers for the class to work

with them either individually or in small groups in which each child has a chance to manipulate them. Occasionally a simple piece of apparatus must be put together, such as a balance for weighing. For elementary school science the materials are quite simple and ordinary, but surprisingly varied. Some of the items can be found readily in variety or hardware stores, supermarkets, drug stores and the like. Metal washers, cups of paper or clear plastic, eye droppers, plastic bags with twist ties, flashlight bulbs, aluminum foil, paper towels, pipe cleaners, planting soil, and other common items are used at various times. Often schools have some more conventional "science" items in their storerooms—beakers, graduated cylinders, better grades of microscopes, substantially constructed scale balances, etc. Some of these will be useful, but the expensive microscopes and balances are not essential except for occasional experiments in the upper grades.

In addition to the familiar items used in a new context, there are pieces that are more specialized. SCIS, for example, requires some specially designed equipment essential for understanding how interactions take place, or to measure the results of an investigation. Pulley systems of various sizes which turn a propeller upon cranking a handle are one example. They can be assembled as needed for purposes of a particular experiment. For the introductory stages of the unit, however, a pre-assembled system with inner workings concealed is used. Plastic plungers are employed in a syringe arrangement with tubing and rubber stoppers to experiment with air pressure. Similar plungers are assembled into a ramp system to project a bottle stopper under controlled conditions. In some units harmless chemicals, such as calcium chloride, are needed. Others require guppies, snails, and other living materials. Some investigations use circuit boards with concealed wiring.

For the individual teacher to attempt to shop for these items, or to find substitutes for equipment that was developed after considerable trial for a specific purpose, is not feasible. Purchasing the many items needed in a K-6 science program by a school through its usual procurement channels, then storing them, maintaining an inventory, and distributing them to classrooms for use when needed is practical if a school-wide system can be developed. Such a system is available, for instance, from an independent supplier for SAPA materials. For the ordinary school, however, management and coordination problems would be horrendous. The materials normally can be obtained at lower cost and far more conveniently in the form of kits designed by the science program distributors.

Kits are shipped by distributors in large corrugated containers that double as storage cabinets. They contain all the ordinary and specialized items required for the teaching of an ESS unit, a semester of SCIS, or a year of SAPA. Similar kits are offered for the suggested student investigations associated with textbook series, such as *Concepts in Science*. Small compartment drawers hold everything the teacher will need for a sequence of lessons, complete with easily followed instructions.

Purchasing kits from a distributor is largely a one-time expenditure. The major part of the initial cost is for items that will be used over and over again, lasting for years with reasonable care. Replacement of expendable supplies is a minor but necessary cost. Living materials for some of the units must also be provided for each class annually. Student workbooks, if they provide space for writing results, will also need replacement, although frequently worksheets can be purchased or even adapted for local reproduction. The "authorized distributor" price lists available in January 1976 form the basis for the following cost estimates.

ESS kits are packaged for 30 children, with an option of kits for 6 children to avoid overpurchase for schools with smaller classes. Their costs vary greatly with the unit. Pattern Blocks and Tangrams are priced in the $20 range for a full class. Kitchen Physics costs about $125, Batteries and Bulbs $130. With such price ranges it is impossible to estimate a school's cost, since each school has great discretion as to which of the 56 units will be used and how they will fit together.

SCIS kits (for 32 pupils) average around $200 for a semester's work, or $400 for a full year's work, over the six elementary grades. SAPA kits (for 30 pupils) average about $340 for the full year's work over all six grades. For both these programs the prices are lower for the earlier grades, higher for the upper grades. Replacements for expendables cost far less than the original kits, as do shipments of living materials keyed to arrive when the appropriate units are covered. Prices vary widely according to items required and packaging arrangements.

The crude approximations given here indicate that the no-text science activities programs may cost up to more than twice as much as an exclusively text reading program with no activities attempted, upon initial installation at current prices. Maintenance of the program from year to year requires a small but continuing investment. There are some economies, however.

The "authorized distributors" are subject to aggressive competition in price and quality of materials by independent distributors. They offer a variety of packaging options which have also spurred the original distributors to flexibility. Mention has already been made that a central school purchase and distributing system for SAPA has been developed which can be considerably cheaper if properly managed. This is possible because there are no patents or copyrights on the equipment designed by the curriculum development groups. Written materials are subject to copyright, and these are purchasable separately from the publishers. Close attention to the offerings of competing firms (including the original distributors) will produce significant savings for all of the science activities programs. Science specialists employed by school systems or teaching in colleges and universities maintain files on potential sources of materials, just as they keep up-to-date on textbooks and professional literature. They should be consulted before decisions are made bearing on program costs.

A very substantial reduction in costs is possible for a large or medium-sized school system through a science materials center that purchases and distributes materials to all schools as needed. The Fairfax County Public Schools in Virginia have organized such a center in support of the ESS curriculum, which is taught in most classrooms of the 130 elementary schools in this system. The staff of their Instructional Materials Processing Center have developed lists of suppliers for every item needed, from screws and wing nuts to brine shrimp. Negotiating for large quantities, they receive individual items and package them with their own part-time help for every classroom to meet delivery schedules. The small microscopes and balances are assembled here, with local improvements in design drawn to their specifications. Equipment is recycled in the Center after use, refurbishing and restocking the kits. Their standards call for each unit to be used in two classrooms each semester, drastically reducing the number of kits needed. Moreover, teachers participate in a continuing program of quality control for the science program. They supply feedback to the Center on equipment malfunctions, difficulties with directions, need for assistance in teaching a unit, how well different aspects of the program are meeting objectives, and other suggestions. The Center staff, in turn, use that information to improve the units, schedule visits to schools and teachers for informal assistance, and otherwise monitor the program. They also conduct more formal in-service training. Adding further depth to the elemen-

tary science program, the Center staff screen books, magazines, pamphlets, pictures, films and non-ESS student investigations, supplying them to the schools on a regular basis.

The Fairfax County materials center is estimated to have cut the costs of supp'ying ESS to the entire school system by half, despite all the overhead costs. The professional staff's functions are largely the same as those performed by science specialists in most school systems, in addition to which they oversee the materials handling functions. Descriptions of the Fairfax County approach to supplying materials and combining them with in-service training have been published.[14]

Other systems use central science materials in similar ways, although they more commonly adopt an intermediate position between ordering kits from distributors and assembling everything locally. Once the initial investment in a center is made, a system-wide science program can be operated at reasonable cost.

In-Service Training

Upgrading elementary teachers' capacities to teach science is necessary wherever it has not yet been done, no matter what the science program. Their undergraduate education has conspicuously not prepared elementary teachers in the content of science nor in the strategies for teaching it. In recent years a small fraction of new teachers entering the profession have actually received such training as undergraduates and are capable of doing the job. They arrive at precisely the time when declining enrollments restrict the hiring of new teachers to the vanishing point. Infusion of competent new professionals to bring modern science teaching into the educational system will not be possible in the foreseeable future. Since the existing teaching staff will dominate the scene for years to come, in-service training is the only solution.

The need for in-service training has been recognized for the proper teaching of inquiry-oriented science, but it applies equally well to even the unrelieved text-reading programs. Not all concepts are clearly understood by most teachers. They need at least one supervised familiarization session with the teacher's edition associated with the text series, together with practice with the required demonstrations

[14] "Supporting an Elementary Science Program Through Community Industry" by D. M. Lapp and L. J. Benton. *Science and Children*, March 1974. "Science by the Package" by E. M. Leeper. *American Education*, August-September 1972.

and the (optional) student exercises. If the science reading class should prove interesting to some of the children, they will ask questions which are not answered in the book, and which the unprepared teacher has not anticipated. Schools that teach science without assuring the competence of their teachers may be wasting instructional time on a non-subject.

Consider the following incident:

> The in-service class was taught by a science specialist every Wednesday from 4:00 to 6:30 P.M. in one of the elementary schools of a large system. On this October afternoon 25 third-grade teachers were present, drawn from an area embracing about 1/5 of the schools in the system. They were preparing to teach the Subsystems and Variables unit from SCIS the following semester. Batteries, flashlight bulbs, wires, and other paraphernalia were at hand. A woman in her middle thirties was sitting on the floor, muttering in frustration that she couldn't keep those darned wires on the battery and the bulb and at the same time cope with that darned board. The task was to find out how a "puzzle circuit board" was wired. It had six buttons on top and hidden wiring sandwiched between two cardboards taped together. By touching the bulb (which had a wire running to the battery) to one button and the wire from the other end of the battery to another button, she was to find out if the buttons were connected. A little help in winding the wire around the bulb was needed, thus freeing her fingers to hold the bulb and battery system as a circuit tester. She then ran through the buttons, touching bulb to one and battery to another. She found only one combination that lit the bulb, when it was on button C and the other end on F. She marked her schematic accordingly. When asked if she had tested every conceivable combination, she said yes. Had she touched the bulb to every button? She thought for a few seconds and then reversed her testing, discovering that bulb on F and battery on C also lit the bulb. She sat back in surprise and exclaimed: "Oh! It's commutative."

How did this small insight affect her? The connection with arithmetic teaching is obvious. Did she use it in class? Did this incident and the rest of her in-service course give her more confidence and enable her to teach SCIS? And what in the world had she been teaching from that nice, secure text she had been using?

Almost all schools spend a portion of their resources on in-service education. The science program needs its share. Here are some recommendations on conducting an elementary school teacher in-service course in science.

Select the staff with great care. The teaching of teachers should be done by professionals who know the content of their subject, are

well-versed in the curriculum being introduced, and know what an elementary school classroom is like from recent personal experience. (If such an injunction seems obvious and unnecessary, let the reader chat with teachers about their in-service experiences.) These competent professionals may be close at hand, on the school system's payroll or perhaps in neighboring colleges. To mention one of many examples, the Boston school system has trained hundreds of teachers in inquiry science, using its own small but select cadre of elementary science specialists located in its own science materials center. In addition, that system has enlisted cooperation from colleges in the vicinity to offer college credit courses. The rewards for teachers participating in the city's in-service program are credit toward merit increases and possession of a valuable science materials kit and accompanying teacher's guide to use in their classroom. Follow-up shows that these teachers use the materials, either as the course of study or supplementary to another program.

In-service sessions may be held for one or two weeks in the summer or after school during the year one or two days a week. Ideally, released time during the school day would be best. It should be as practical as possible. Hands-on experience for the teacher is the most important single ingredient. The tone of the class should be set so that a participant may make mistakes, appear clumsy or ignorant without blame or ridicule; experience has shown that initial ineptness should be expected. Practice in and understanding of beginning skills and concepts must be open to all those who need them (perhaps the majority of participants). Permitting the better-equipped teacher to help the less confident is a useful technique. It takes empathy and patience.

A predominantly lecture in-service course is counter-productive. Set an example as to how the teacher is to perform in his own classroom. Demonstrations should be related to the concepts and materials that will confront the teacher in his own classroom. Immediacy of content to the teaching task is the objective. Video-taped mini-lessons permit participants to try out new techniques while not on the firing line. Finally, a "hot line" to the in-service instructor is invaluable for a teacher struggling with new skills.

The value of local science specialists has been mentioned. A large proportion of such specialists at the elementary level are skilled with inquiry materials. They should be involved as staff members of in-service training courses. In the seven years since inquiry science

began to spread, thousands of teachers have assimilated the ideas and strategies needed and are applying them in their classrooms. For the most part, these teachers have had years of prior experience working solely from textbooks.

The procedures described will be recognized as the familiar teacher workshop. Many observers would prefer more fundamental measures, such as formal instruction in science for teachers. Aside from the costs in time and dollars, however, elementary school teachers are simply not going to take several courses each in biology, chemistry, physics, and earth science, followed by additional courses on relating those formal subjects to the elementary school curriculum. If science teaching is to change for the better in the 1970s and 1980s, it will require immediate help that the teacher can absorb and is willing to accept, and that is also within the scope of the school system's ability to accomplish. Providing the practical help needed for a year's work in the classroom is a successful technique. It does not make for science specialists, but it does bring better science to the children.

SHOULD SCIENCE BE TAUGHT BY A SPECIALIST?

One solution to the inadequacy of the typical elementary school teacher in science, and the consequent need for in-service education on a large scale, might be delegation of science teaching to a specialist. Housed in an average school of 20 classrooms, the specialist can offer one period a week to lower grades and two to upper grades, assuming six classes a day for five days. That is a heavy schedule for so many grade levels; preparation time must be squeezed in between. An alternative is confining the specialist to the upper grades, which need greater depth. Science in the primary grades would then be left to the regular teacher. There are some administrative difficulties in the latter arrangement, for upper-grade teachers would have more free periods than lower-grade teachers. Besides, lower-grade teachers would have an extra subject to cover. This problem must be overcome by some administrative device.

Pros and cons of the specialist arrangement have been debated inconclusively. Some studies of the issue do not show any better performance by students taught by science specialists when many different situations are combined, but still left open is the question of what happens under optimal conditions. One will find research supporting either side.

The specialist is an extra teacher in the school, probably at the top of the ladder because of experience and educational prerequisites. That is an added cost. Supply and equipment demands are different from those in a school with a materials kit for each teacher, but initial equipping would probably demand more sophisticated apparatus and a secure storage space. Moreover, if some science teaching still occurs in some self-contained classrooms, expenses for those classes will still be entailed. A perhaps minor consideration is that a single science classroom can become too crowded with ongoing student or class projects from so many classes, since projects extend over periods of time and require precise light or temperature exposures, etc. Spread over the 20 classrooms in the school, projects may remain undisturbed without piling up.

Selection of a specialist is a delicate issue. The large number required to place one or more in each school would probably exceed the existing pool of persons with the proper combination of content knowledge and personal traits. To insure objectivity and to prevent favoritism in appointments, candidates would be inevitably rated

according to paper qualifications and seniority, in some cases together with an examination. Each of these prerequisites is only vaguely related to good science teaching, and the combination can easily place at the top persons with the characteristics and orientation of a high school science teacher. A far different perspective is desirable for elementary school children. If a good teacher is found, the school has a decided asset. If the teacher is unsuited to the job, the whole school's science program is damaged while costs have been added. Examples of poorly selected specialists are sufficiently numerous for the appointment procedure to become a hazard. Getting rid of a teacher with seniority can be an exhausting fight.

Often the case for an in-school science specialist cannot be made on the merits of this subject alone. Policies on specialists in other fields—music, art, physical education—are part of the larger picture. In those fields the specialist is frequently shared by two or more schools; that arrangement for science is not viable.

One of the strong arguments for teaching science in the self-contained classroom is the opportunity to refer to other subjects. Math skills can be exercised in the science lesson, while subject matter from science can be brought into reading, math, and social studies. The regular classroom teacher can accommodate to the known strengths and weaknesses of each child, even his daily ups and downs.

Although the issue has many ramifications, a better job of teaching science to children will probably take place in the self-contained classroom, provided that the teacher is helped to become minimally competent. A full-time specialist in the building tends to introduce strains in the system. The best use of a demonstrably good specialist is as a science consultant available to many teachers to help them with their teaching problems, and to conduct training in formal and informal settings.

Incidentally, the Pennsylvania survey in 1971-72 showed that almost 40% of the schools in that state used departmentalization for science—nearly, but not quite the same thing as specialists—in the fifth and sixth grades, but practically none in grades 1-3.

THE NEW BREED: TEXT AND ACTIVITY ENTWINED

Scene from a Classroom

The third-grade class has 28 of its usual 30 present today. Tables are grouped with an open space in the middle. Science texts lie unopened on each table. A lidless shoe box is placed on a table top in the center. The teacher asks, *Is this box empty?* The discussion is scant and inconclusive. The lid to the box is sealed on with masking tape. *Is there anything in the box?* "No" in a chorus. After a pause, a voice pipes up: "Air?" *What evidence could we find to show whether there is air in the box?* "Let the air out." *How?* "Take the top off." "Through a hole." A small hole is punched into one end. Nothing visible happens. *How can we make air come out?* "Can we squeeze it?" "It would come out of the hole." The top is pressed and a puff is felt. The teacher places scraps of paper on the center table and asks a child to push top and bottom of the box like a bellows. The papers scatter. The child with the box points it at herself and makes her hair blow. *Was the box empty?* "No. There was air in it." *What is your evidence for saying that?* "It moved the papers." "I could feel it."

Let's open our books to page . . . Marjorie, you may start reading. The passage begins "Air can move things." It describes how air pushes against things to move them, offering several examples. There are drawings of air pushing against objects. Calling attention to air blowing clothes on a clothesline, the text asks what happens when the clothes are removed. The teacher repeats the question. The air is still pushing against the line, the children agree. *How would you know that?* Some children doubt that the line would move. *Can we test it in the classroom?* The children suggest tying a string between tables and operating the shoe box bellows. One team ties, another team observes, and a "strong person" pushes the bellows. The observers report a sudden, but small movement. Another team of observers looks closely and verifies. *Is the rest of the class satisfied with the evidence reported?* Three more children who were sitting toward the back want to observe. They verify. Another demonstration of moving air is made by rapidly opening the closet door to move objects.

The book asks, "Can air move tiny objects? Can it move dust?" The teacher repeats the question. *Where can we find dust in this room?* "On the floor." "Behind the fish tank." "In the air." "You can see dust moving up and down at the window." *What makes you able to see it?* "The sun is shining through the window." *What makes the dust move?* "Air." "Moving air." *What makes the air move?* "I did when I walked over." "I just blew it." They stand still. After a minute some observers walk over cautiously to the sunbeam. "The dust is still moving up and down." "Air still moves it." *Why is the air*

moving? No answer. *Put your hand in the sunbeam. What do you notice?* "It's warm." "Over here it's colder." "It's like a draft."

Discussion on the source of the warm air, and why there is a draft, leads to mention of the warmth in sunlight. But the subject is complex and further discussion is reserved to another day.

Teams of four children are formed. Their text gives directions for several experiments. Medium-sized plastic bags and twist ties for the bags are distributed to three teams. The other teams have pieces of string and cardboards taken from laundered shirts. Each team reads and follows its own directions, with the help of picture diagrams. The plastic bags are crumpled and thrown, then inflated, tied, and thrown. Different trajectories are recorded. Several inflated bags are brought together to support weights. A child lies across them. Explanations are sought.

The cardboards are dropped, one edgewise, the other flat (parallel to the floor). Differences are noted in time of drop and noise made upon hitting the floor. Loops of string are tied to the ends of the cardboard. It is laid flat on a table. Pictured directions show paper scraps placed around the edges. Their instructions tell them to lift the cardboard very rapidly by the strings and observe. The book asks, "What happens to the paper? Can you think of a reason why?" The paper blows inward, beneath where the board lay. Not a word of that result is in the book. The children must observe and explain to the class. The children also note that there is a pressure against the top of the cardboard when it is lifted. Each child has a turn. This observation must enter into their explanations of what has happened.

Textbooks, Post-1970

The sample of classroom teaching given above is a composite taken from two classes. There were additional demonstrations and experiments with air pressure and the properties of warm and cold air. Compare this class with the one using a traditional text given earlier.

Although this is a text-based program, it is also activity-oriented. The text is one of a hybrid new breed that employs student explorations to make the text usable. Several such text series have appeared since 1972, varying in their integration of student activity. At their best, the continuity of a lesson depends on student involvement in relevant investigation. Results of the investigations do not appear in the text. Follow-up discussion is guided by the book and the teacher with students' experimental results central to the discussion. In the lesson above, the reading/recitation surrounding the investigations supplies additional insights through pupil contributions, written explanations, and drawings in the book. Writing such a text is difficult.

Not all of the attempts to combine the two approaches are equally successful. Even the best are uneven in their ability to sustain the effort.

Many of the activities shown in these hybrid texts have been adapted from ESS, SAPA, and SCIS, more so in some of the series than in others. Pictures of materials and apparatus will be recognized by persons familiar with those programs.

Publishers of the new series announce that they will sell kits for the hands-on portions. They also encourage use of materials that are already in the school supply cabinet or otherwise procurable. In many cases it is possible to find the required materials elsewhere, although all too often teachers will be unable to collect very much from outside sources. One practical difficulty is how to reimburse the teacher who purchases materials for his class.

One gimmick recently introduced by at least one publisher has been a table showing items that may be requested from each of several sources, including contributions from the homes of pupils. Cross-reference lists are also available enumerating the items taken from units of ESS, SAPA or SCIS that can be used in a given exercise in the new text, complete with catalogue number from the original distributor's catalogue. The impression is unmistakable that these new texts have been designed to capitalize on schools that are not happy with their no-text inquiry programs, but that nevertheless do not wish to abandon the central position of student investigations. Certainly the new programs have borrowed copiously from the ideas, materials, and phrases of the big projects, including the SAPA-style science processes.

The new series are known by their acronyms. Houghton Mifflin has MAPS (Modular Activities Program in Science). McGraw-Hill publishes PCP (Science: People, Concepts, Processes). Rand McNally has produced ESLI (Elementary Science: Learning by Investigating). Ginn and Company calls its entry GSP (Ginn Science Program). STEM (Space, Time, Energy, Matter) comes from Addison-Wesley. There are others, and the interested reader is invited to investigate further, but these seem to have attracted the most attention. Worth mentioning is the fact that McGraw-Hill, Ginn, and Rand McNally—distributors respectively of ESS, SAPA, and SCIS—have now published their own programs integrating investigations with text. Although there is an obvious competition, in each case so far growth seems to be continuing in both the text and no-text approaches.

The older text series of traditional format have attempted to compete in this market as they bring out new editions. They use the process charts popularized by SAPA and adapted to their own materials, and introduce the code words *student inquiry* liberally. There is a forced quality about these attempts, and they do not appear to have accomplished the objective very well. To revise an existing text and embed investigation into the continuity seems exceedingly difficult. The products retain their traditional flavor. Apparently only a fresh start will do the job.

The new-breed texts are a distinct improvement over the pre-1970 texts. They differ from each other as well. The themes given in their titles are one illustration of differences, perhaps more selling point than real at times. STEM seems to have borrowed least from the no-text inquiry materials, yet here the publisher demonstrates how most of the student activity can be supplied with materials by cannibalizing kits which the school may have lying around. Classes using STEM were the basis for the classroom scene at the beginning of this section.

Each of the new series has some commendable arrangements. MAPS, for example, has published its themes in separate soft-covered student books that give instructions and are designed to relieve the teacher of some of the burden of starting each investigation. As do the other series, MAPS has made a determined effort to keep its equipment simpler and less costly than the no-text programs. MAPS also offers suggestions for materials management in a school building which appear quite practical and can save money. It is reminiscent of the system developed by the Oregon Museum of Science and Industry for the management of SAPA, but with differences. The Fairfax County approach would also work well for such programs.

Use of the new programs will not free the school of concern for its science program. There is still a need for in-service training. Materials must still be obtained and stored. The danger of misusing the text warrants continuous vigilance. It is possible for an insecure teacher to sabotage the intent of the program by resorting to demonstration alone instead of student work. Teachers may still skip portions they are afraid to teach. Adequate supervision will be needed, just as it always has been needed. Moreover, the approach is new, and there may be hidden snares not visible at first glance. Re-evaluation after trial should be of high priority.

None of these series achieves its goal entirely. Each has investigations that miss the target in being too prescriptive, suffering in comparison in several cases with the parent unit in the no-text projects from which they were borrowed. Some errors or oversimplifications have crept in, and these are always embarrassing in print. A more incisive critique of the new science texts than can be presented in this overall summary may be found in an article by O. E. Dyrli.[15] Before choosing one of the texts discussed here Dyrli's comments should be digested.

Despite these words of caution, the new texts offer help to teachers who feel a need for the guidance of a text, but who also want to integrate selected student investigations into the science lesson. These programs are a decided asset for such teachers.

[15] "Is There Anything New About the New Science Textbooks?" by O. E. Dyrli. *Learning*, January 1976.

HOW GOOD IS SCIENCE TEACHING IN YOUR SCHOOL?

There is no trouble-free road to good science teaching. Science is no different in this respect from the other important academic elementary subjects: reading, mathematics, language, and the social studies. Each subject area has its own obstacles and, in extreme cases, chamber of horrors. Schools intending to improve their offerings in science may find the following suggestions helpful.

Four conditions are prerequisite to a good science program: sympathy from the central administration, reasonably high priority from the school principal, willingness of the teachers to devote time to teaching it as well as to learning how to teach it, and a sound course of study. The first three are commitments, the last is a complex of choices.

Support from the top level of administration and the principal is fundamental. Without it, teachers have no incentive for improvement or for maintaining high standards in a subject they perceive as being considered unimportant. The hypocrisy of high-flown educational goals in publicly displayed documents and apathy in practice is not lost on them. The public has a right to object when this is the case.

Top-level support is shown by sincere acknowledgement of the unique values science can bring to the education of children. It is openly expressed by specific goals and objectives in the curriculum. Teachers and schools performing well receive recognition. That commitment from key administrators has a price tag. In resources and energy it means:

- in-service training on a planned schedule by competent trainers;
- weaning teachers from total reliance on reading science from textbooks and developing their capacities to lead investigative studies;
- assignment of competent subject-area specialists to work with teachers and keep the program alive;
- funds set aside for apparatus and materials children may use in their science investigations.

If a school district has the commitment, its course of study should be chosen with great care. Selection of a science program occurs on two levels: the school system and the individual school. Expert assistance is absolutely essential in selecting the science programs a system should permit in its schools. The technical considerations should be in the hands of knowledgeable science education specialists. The system may have such people on its staff, able to lead committees in

examining alternatives. It is suggested that they be supplemented with consultants who have had extensive experience with elementary school investigative programs. Qualified consultants may be found in universities or neighboring school systems.

Once a number of programs have been identified which reflect the system's philosophy of instruction, each school should be permitted to select its own program(s) from among these. Since student investigations should be at the core of science teaching, the principal and teachers in a school should have a personal commitment to the program chosen. Once the school decision is made, however, restrictions will necessarily be made on the choices of individual teachers. As children move from grade to grade they must build on earlier experiences, so a coherent program throughout the building is required. Nevertheless, a teacher ought to have several auxiliary sources in the classroom to promote breadth of coverage, as long as the continuity of the program is maintained.

Consultant help should not stop at the system level. Expertise should be made available to the local schools when they are making their decisions. This is the point where program selection may break down, for most schools have limited time to choose, and their staffs may be deceived by superficial appearances, not understanding the implications of all they see.

As the school chooses its program, the staff should consider how comfortable they would be with the different approaches to teaching and supervision embodied in each. The no-text, inquiry programs are quite different from each other, and each has strong advocates. Similarly, the new text-plus-activity programs require different styles. All imply an obligation to acquire, use, and store materials. All require in-service training and support from science specialists.

The role of publisher representatives needs to be clarified. They should not be permitted to use sales techniques, particularly with individual school staffs. If they would like to demonstrate their packages, ground rules should be followed. Of course they ought to be available to respond to requests for prices and delivery schedules, trial of samples of equipment, authenticating publisher claims about pre-publication trial of the program, publisher services, or provisions for assisting in the in-service training process. The merits of their programs can best be determined by critical analysis, and by evaluating their use under conditions similar to those in the local schools. Once a decision is made, a conscientious publisher representative can be invaluable.

Guidelines for selecting science programs vary from the *ad hoc* to the elaborate and formal. Whatever the technique, some criteria are indispensable. Program quality is the primary consideration, with costs of various types and personal preferences inevitably entering into the final judgments. A word might be introduced at this point about the hidden costs in wasted effort and breaking faith with the public in settling for a low-quality, apparently cheap program.

Most selection committees start with a checklist of quality criteria. It should include many elements peculiar to science teaching as well as the more general ones educators use in evaluating programs. Application of a lengthy checklist to a dozen or more programs is a technical, arduous task. Written materials and physical objects for every grade level from K through 6 must be examined. Continuity for all grades and within a single grade is just one of the elements requiring broad judgments. Just as necessary is a detailed review of each unit for a single grade. Although no attempt will be made here to present a comprehensive list of quality criteria, several important points will be discussed below for emphasis.

Upholding quality as the primary basis for program determination, the choice will lie between the no-text, inquiry options and the recently appearing text-plus-activity programs, or perhaps some combinations among them. The traditional texts that simply dispense information are not recommended. The major no-text programs will be found to meet all the modern criteria of quality. They may be considered as having established many of the most important criteria. One will find general agreement that they are the standard against which other programs are measured. Choices are made among them, or to reject all of them, not on the basis of intrinsic quality but for other reasons. A large body of literature exists as to how well each program meets user goals. Other articles discuss aspects of their use in the classroom, resolving problems of implementation, management of materials, or modifications for special needs. Pros and cons have been debated at length. Moreover, there is impressive evidence that hands-on science increases achievement in reading and math in the early grades.[16]

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[16] *The Effect of Selected Science Activities on the Attainment of Reading Readiness Skills with Kindergarten Children* by D. E. Maxwell. A doctoral thesis submitted to Michigan State University, 1974. "An Evaluation of the Science Curriculum Improvement Study" by J. W. Renner, D. G. Stafford, W. J. Coffia, D. H. Kellogg, and M. C. Weber. *School Science and Mathematics*, April 1973. "Help Is Denied to Those in Need" by M. B. Rowe. *Science and Children*, March 1975.

If the school's choice is to have a modern text series as the program, or as one option among several, less information is available about these series in actual use. It would be well to locate communities that have tried them for a rundown of strengths and weaknesses. A first question is how well the program meets its promise, whatever the promotional literature says. Since each program has a statement of its goals, that is one basis for evaluating it in practice.

One place to start in reviewing any text series is to compare it with earlier texts by the same publisher, or even books of the 1960's by other publishers. Look for major themes, treatment of topics, suggested student exercises, even the photographs and drawings. If there is extensive overlap in printed materials, that raises a warning flag, for the defects of the earlier book may be reproduced in this one.

An experienced science teacher often finds it revealing to try several passages from a text with a class. How do the children respond? Is there a tendency for questions to be rhetorical, answerable by a simple "yes" or "no" instead of generating some thought? Even worse, are the questions answerable merely by reading ahead in the text for the next page or two?

Some critics have noted in a few of the newer texts a tendency to degenerate into the question-and-answer routine so objectionable in traditional texts. There are places the teacher will be able to substitute demonstrations for student investigations. Sometimes suggested investigations are poorly related to the text content. If this occurs frequently, the text is too prone to mishandling, and it misses its mark.

Reading difficulty, particularly at the upper levels, should be determined. A major complaint about traditional texts has been the wordiness of the books intended for the fourth, fifth and especially the sixth grade. Do the concepts become so abstract that the child's only defense is to memorize the words in the book? At the lower grade levels, does the text carry the child too quickly into abstractions?

Authorship of a text series is important. Scientific pedigree does count, provided that the content has been written in terms a child can understand. If genuine scientists are responsible for the content, there is some assurance that important ideas have been accurately stated and that factual errors are minimized. Without that pedigree the series may be deficient. There is a caveat, however. Not every big name on the title page has actually contributed as much as is implied.

Since it is not possible for a local committee to know the extent to which this may be true, careful reading of some sample passages may identify some weaknesses. These shortcomings will be revealed as the new books become more widely used. Reviews in professional journals will help, as will the exchange of information within the network of professionals who keep up to date. Dyrli's article, to which reference has already been made, contains some interesting information in this respect.[17]

Extensive trial of a new program before placing it on the market is a safeguard for the user. Evidence of the tryout procedures should be reported in the publisher's literature. Comparing several series for the size and diversity of their tryout populations, especially to see whether they resemble that of the local school, is a common practice.

The science program should have measures for achievement of students at all levels, or at the very least some detailed suggestions for this purpose. The classroom teacher should not be left with the chore of developing comprehensive tests or class performance indices for a subject with complex objectives. The result of falling back on teacher-made tests is inevitably memorization of facts and definitions. Assuming that there are publisher's student evaluation devices, do they meet the school's objectives? Do they really meet the publisher's announced objectives? How much do they cost? Most series will supply masters for local duplication. These will probably be for both tests and student worksheets, which are invaluable for measuring pupil progress.

Although a publisher may offer supplementary films or pamphlets for student use, a competent science specialist can probably augment the list. Practically every science program has developed some very good ancillary materials which may be inserted at the appropriate time in almost any other program. Such materials are also available from other sources. When properly used they add a great deal in learning and interest to the total educational program.

A wise precaution is checking in detail the list of equipment and student materials the program requires. If the publisher states that they can be collected from local sources, are all the essential items really available? What are the full costs of collecting them, not just the cash outlay at the retail store? If the publisher offers a kit, what is the experience of others with this kit? Will it arrive on time?

[17] "Is There Anything New About the New Science Textbooks?" by O. E. Dyrli. *Learning*, January 1976.

The last item to be mentioned here, though by no means the last which would be on a comprehensive list of quality criteria, is provision for in-service training. The publisher's complete package should have a very good teacher's edition of the text, materials for teacher self-study, and the essentials for a formal in-service course. Ignoring the need for in-service is a bad sign. If the publisher implies that the average teacher can take the book and auxiliary materials and, by carefully following directions, successfully implement the program, be extremely skeptical. There is a skill required to meld activity and text, just as skill is required to handle inquiry without text. These skills must be consciously addressed and practiced.

In brief, these are some of the important elements reflecting on the quality of a science program. There are others, but they tend to be quite technical. A "buyer beware" attitude beforehand can save grief later. Actual choice will also be governed by other philosophical, educational, economic, administrative, and personal considerations. When a school finds a program that meets its goals and satisfies the important quality criteria, it is ready to offer a worthwhile education in science to its children—if the school and the district sustain their commitment.

A FINAL WORD

This paper advocates that:

1. Every child in elementary school should have a science class for three or more periods a week. To have no science taught at all, or to schedule an expendable one period a week that is seldom given, creates an educational disadvantage which occurs much too often. Science is the subject best adapted to help younger children develop critical thinking abilities, positive attitudes toward their environment, and an understanding of the world they live in.
2. Science is best taught at the elementary school as a "hands-on" subject, a *doing* instead of a *reading* activity. Simple materials are needed to provide interesting experiences while the setting provokes coherent thought about their meaning. The basic processes used in science—observing, describing, comparing, classifying, measuring, using numbers, interpreting evidence, inferring, predicting, experimenting—are such fundamental skills that they should be developed during the formative years in an activity-based science program.
3. Elementary science activities should be carefully linked for a progression of skills, knowledge, and concepts. The subject should be taught by the regularly assigned teacher in a self-contained classroom, at least through the fourth grade.
4. Textbook series in general tend to thwart development of some of the most important outcomes desired in teaching elementary science. They should not be used unless frequent science activity for all children is embedded in the program. Even at their best most textbooks have an inhibiting effect on the basic science-related skills. Non-text programs are available which assist the teacher in developing process skills and introducing science content suitable for these age groups. There is even evidence that using such activities as the core for teaching science in a self-contained classroom promotes reading and arithmetic achievement for all students, but particularly for the educationally disadvantaged.

Although student activity has been emphasized as the core around which the elementary school science program should be constructed, reading has a definite place in the total program. One of the fundamental teaching/learning objectives is to help the children find out for themselves, and learn how to find out. Often it is by reading.

Moreover, many topics or whole fields of science may not be covered by the curriculum followed by the school, and readings will open the door to these. Books, pamphlets and magazines should be in plentiful supply in the school building, and they should be used. Nevertheless, a large part of the learning must come from experience. Discovering how to light up the bulb and what else can be done with batteries, cutting up a battery to see how it works, feeling the effects of air pressure, learning to measure the results of one's own experimentation— these are sensory and intellectual experiences. These are events that happen to a child; reading is vicarious. Both have their place.

Science is not merely a collection of facts printed in an encyclopedia. It is a living adventure of human spirit. On any day some fascinating discovery may be announced, some wonderful insight into a seemingly mysterious process be achieved. In a few years we have learned much about how the continents move over the earth's more plastic interior, and with this understanding have formed some better explanations (theories) of the cause of earthquakes and volcanic eruptions, and also why mountains rise. We have discovered more about how living creatures adapt to environmental change, and also how small changes may be disastrous to them. Advances in medicine and frustrating searches for cures for diseases are common topics of conversation. Growth and handling of genetic materials to overcome inherent defects is near, for better or worse. So many exciting possibilities are within view!

Our children will grow up in the world that has to cope with these discoveries and those yet to come. The processes and basic concepts which can be introduced to them before the age of eleven give them a genuine feeling for their world, and how they can learn more about it. Dispelling the mystery, often fear, of science and of those who are engaged in science-related professions may be one of the more profound effects of early science teaching. Practice in rational thinking while children are young and understanding the difference between superstition and scientific evidence are two of the goals of education. All of these goals are achievable, and the sciences are the most likely avenue by which they will be reached.

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